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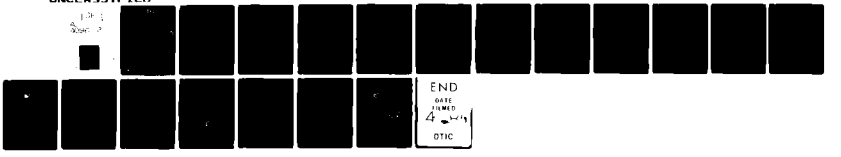

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FINAL REPORT

OCS OPERATIONS—NOW AND TOMORROW.

Research and Development Program
for OCS Oil and Gas Operations.

November 1979

Prepared By
Booz, Allen & Hamilton Inc., Bethesda MD

for
U.S. Department of Interior
Geological Survey

OCS OPERATIONS—NOW AND TOMORROW

The United States is placing an increasing reliance on offshore oil and gas operations to supply energy. The importance of these operations has increased as the need for energy has increased.

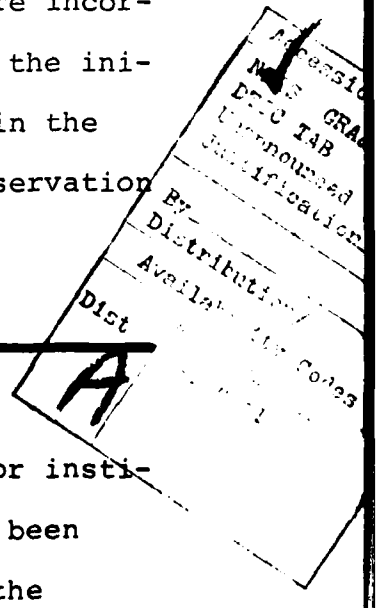
Accelerated exploration and development activities on the Outer Continental Shelf, however, are intensifying public concern about the safety and the environmental effects of these operations. More drilling and more operations in deeper water, remote locations, and more hostile environments threaten to lead to more environmental risk and risk of human life.

National attention to potential dangers was first aroused by the Santa Barbara oil spill in 1969. Nationwide concern was increased the following year when an oil and gas platform in the Gulf of Mexico caught fire. Obviously, something had to be done to protect the marine environment and safeguard life and property.

Several major studies, including those by NASA, the Marine Board of the National Academy of Engineering, and the University of Oklahoma, were undertaken in the early seventies. These studies pointed out deficiencies in

antipollution equipment, personnel safety, and operational procedures in OCS oil and gas development. Recommendations focused on the need for active Government encouragement and sponsorship to develop systems and techniques to improve damage control, fire fighting, and well control. In addition, the following strategic recommendation was made: "USGS should undertake an expanded research, development, and testing program as necessary to insure optimal regulation and rapid development of new equipment and procedures."

During this period, the Geological Survey was extensively reviewing its OCS lease regulatory program and produced several recommendations for program improvement. These recommendations and those of other studies were carefully assessed and those considered appropriate were incorporated in the USGS program. One major action was the initiation of a research and development program within the Branch of Marine Oil and Gas Operations of the Conservation Division of the Survey.



Why the Geological Survey?

The Geological Survey was uniquely suitable for instituting this vital program. The Survey had already been given the mandate to administer the provisions of the Federal regulations pertaining to oil and gas operations on the Outer Continental Shelf (30 CFR Part 250). With these regulations came the responsibility to "prevent damage to, or waste of, any natural resource or injury to life or property."

In administering these regulations, USGS had gained extensive experience in OCS operations. The Survey was familiar with the problems and with the people and equipment involved in these operations. The Survey was already concerned about safety, prevention of pollution, protection of life and property, and minimizing the risk of environmental damage. It had made studies of its own and had commissioned studies by other organizations.

What Kind of R&D Program?

In initiating an R&D program, the Survey had to determine the best way to go about doing the research. Because it was imperative to obtain the best scientific and technological information and because of the varying technologies involved, the Survey established a contract research program.

A contract research program makes it possible for the Survey to maintain an outstanding research and development capability. Top scientists and technicians from all over the country can be contracted to work together on a single project.

As a result, the program has come up with some exciting concepts, such as a free-swimming robot for underwater inspection, a hand-held gun-like cleaning device for underwater structures, and refraction of surface waves in the

open ocean for safe launching and retrieving of divers and submersibles.

The broad and continuing objectives of the R&D program are to ensure the availability of the maximum benefits of science and technology for fostering safety, preventing pollution, and conserving the resources during oil and gas operations. Technology assessments are necessary to identify technological needs for research and to determine the best available and safest technologies (BAST) required for new drilling and production operations.

What Are the Research Projects?

More than 30 R&D projects have been sponsored by the Geological Survey to investigate environmental and safety concerns in OCS oil and gas development. These projects have focused on three specific research areas: well control, structures and pipelines verification,and environmental concerns. Table 1 summarizes the key elements of the R&D program.

Specific goals and priorities are established to emphasize the immediacy of these concerns. Of highest priority are the prevention of blowouts and the verification of offshore structural design. Blowouts are the most traumatic occurrences that can befall OCS operations from all points of view: economic, environmental, and safety. Though they occur

TABLE 1
Summary of USGS' Program in Outer Continental Shelf Oil and Gas Operations

Research Project	Objective	Organization/Project Manager
Well Control/Safety		
Casing Wall Thickness Technology	Investigation into techniques for measuring casing wall thickness	Hydro Tech Systems Mr. David Adkins
Technology Assessment for Cementing Shallow Casings	A study of the cementing practices applied to shallow casings in offshore wells	Maurer Engineering Dr. William J. McDonald
Detection and Suppression of Wellhead Fires	Examination of fire phenomena resulting from blowouts on offshore drilling platforms and investigation of technologies for detecting and suppressing ignitions	National Bureau of Standards Mr. John O'Neill
Technology Assessment for Estimating Hydrocarbons Lost During a Blowout	A survey of the methods used and recommendations for new technology to assess the hydrocarbons lost during blowouts	Coastal Petroleum Associates, Inc. Mr. Murray Hawkins
Underwater Acoustic Telemetry	Development of a technique for transmitting underwater information by means of digital acoustic telemetry between a transmitter and receiver	Ocean Electronics Applications Dr. Eric Softley
Overpressured Marine Sediments	Investigation of the formation of overpressured marine sediments in order to predict their occurrence during drilling operations	Texas A&M Research Foundation Drs. L. Thompson and W. Bryant
Fire Suppression Technology	Assessment and identification of R&D needed to prevent, suppress, and fight enclosed and open fires on offshore platforms	Harry Diamond Laboratories Mr. Dan Finger
Fluidic Sensor for Hydrocarbon and Hydrogen Sulfide Gas	Development of technology for sensing H_2S and hydrocarbon gas on an offshore structure by means of a fluidic gas concentration sensor	Tri Tec Mr. Maurice Funke
Fluidic Pulser for Mud Pulse Telemetry	Development of technology for using fluidic controlled flow for mud pulse telemetry	Harry Diamond Laboratories Mr. Allen Holmes
Blowout Prevention Procedures for Deepwater Drilling	Development of improved well control procedures by obtaining in situ experimental data to evaluate mathematical analyses and rule of thumb assumptions used in controlling the flow of drill muds	Louisiana State University Dr. William Holden

TABLE 1 (Continued)

Research Project	Objective	Organization/Project Manager
Structures and Pipeline Verification		
Acoustic Imaging Technology for Underwater Inspection	Investigation of underwater acoustic imaging techniques for the gross inspection of structures and pipelines	Naval Ocean Systems Center Dr. Albert Gordon
Deepwater Structure Technology Assessment	Investigation into deep-water structures technology and an evaluation of the use of "coupon" gauges for detecting fatigue failures in structures	Battelle, Houston Dr. Jay Mandke
Incipient Structural Failure by the Random Decrement Method	Investigation of a method of nondestructive evaluation of a structure by periodic recording and filtering of its natural vibration response signature to obtain changes in structural damping	University of Maryland Dr. Jackson Yang
Portable Data Recorder for USGS Inspectors	Development of a "breadboard" portable data recording system that could be used by Government inspectors to obtain both digital and verbal data during periodic inspections of offshore installations	Harry Diamond Laboratories Mr. Edward Burke
Ultrasonic Flowmeter Evaluation	Evaluation of four designs of ultrasonic flowmeters by quantifying ability to detect leaks in pipelines	Harry Diamond Laboratories Mr. Allen Holmes
Unmanned, Untethered Inspection Vehicle Technology	Development and evaluation of navigation, data sensing, storage, and telemetry technology for a free-swimming robot submersible programmed to inspect underwater pipelines and structures	Naval Ocean Systems Center, San Diego Mr. Paul Heckman
Research Program Advisory	Advice on research, underwater inspection, and inter-agency cooperation	Marine Board, National Academy of Engineering Mr. Jack Boller
Attenuating Surface Waves in a Localized Region of the Open Ocean	Investigation of the refraction of surface waves from a localized area of the open ocean for purposes of launching and retrieving divers and submersibles as well as smoothing water where divers are working	Stevens Institute of Technology Dr. R. I. Hires

TABLE 1 (Continued)

Research Project	Objective	Organization/Project Manager
Structures and Pipeline Verification (Continued)		
Cavitating Water Jet Cleaning Nozzle	Harnessing of the destructive forces of cavitation erosion in a water jet nozzle for cleaning underwater structural joints	Daedalean Associates, Inc. Dr. A. P. Thiruvengadam
Incipient Crack Detection in Offshore Structures	Development of a nondestructive evaluation (NDE) technique for detecting incipient cracking by means of monitoring the internal damping characteristics of a structure	Daedalean Associates, Inc. Dr. A. G. Hochrein
Dynamic Response of Offshore Structures	Identification of structural response properties (such as natural frequencies, damping, and modal shapes) from field data; assessment of the importance of damping in the response of structures to wave excitation	Massachusetts Institute of Technology Ms. Kim Vandiver
Environmental Concerns		
Overpressures Developed by Shaped Explosive Charges Used To Remove Wellheads	Assisting the USGS Area Office, Anchorage, in quantifying the environmental effects from blowing-off wellheads by use of shaped charges	Naval Surface Weapons Center Mr. Donald Phillips
Toxic Effects of Drill Mud on Coral	Quantification of the effects of whole drilling muds on corals and the quantification of the extensiveness and chemical consistencies of mud plumes	USGS - Fisher Island Station Mr. Gene Shinn
Technology Assessment for OCS Oil and Gas Operations in the Arctic Ocean	Assessment of the status of technology and identification of needed R&D for OCS operations in the ice-covered Arctic Ocean	Energy Interface Associates Mr. William Brown

infrequently, overwhelming concern for their prevention requires highest priority attention.

The Survey is also embarking on a new program that involves guidelines for structural design and inspection. Although the Survey does not regulate underwater inspection of structures, new technology for such measures is rapidly unfolding and needs to be sorted out by those who may become involved.

What Are Some Program Achievements?

Several projects stand out as representative of the timeliness of the studies, the quality of the research, and the effectiveness of the program.

First, is the USGS's program in blowout prevention. From all points of view—economic, environmental, and safety—blowouts can cause severe dislocations. Many studies have concluded that a prime area of research to minimize blowouts is to incorporate elements of human behavioral patterns into OCS technology designs, with emphasis on evolutionary damage-limiting and failsafe systems and techniques.

For example, as the search for petroleum reserves moves farther offshore, the problem of controlling well kicks (threatened blowouts) during exploratory and development drilling becomes more complex. Modern well control

equipment was developed for land-based drilling operations and has proved satisfactory for shallow water depths where drilling platforms are bottom founded. But in deeper waters (greater than 1,000 ft), where floating platforms are required, it is necessary to locate the blowout preventer valves on the sea floor instead of at the surface. The flow of fluids is difficult to control in the long subsea choke lines between the blowout preventer and the drilling ship.

Recognizing the need for additional research in this area, the R&D program has contracted with Dr. William R. Holden, whose ongoing program at Louisiana State University involves the development of improved well control procedures for floating drilling operations. An experimental well for modeling deep-water drilling operations, together with surface support equipment, has been designed. Also, experimental data are being obtained at the university's training facility well on the flow characteristics of modern adjustable chokes and blowout preventers. Using mathematical modeling to simulate the various control configurations, studies are being conducted to determine the optimum man/machine interface and operational procedures for blowout prevention during deep-water drilling.

Another area of prime concern to the public and to the USGS is the underwater inspection of oil and gas pipelines

and structures, for both leak detection and structure fatigue or corrosion. Up to now divers and manned submersibles have been employed to inspect and monitor the conditions of underwater pipelines and structures. As oil and gas drilling ventures into deeper and more hostile waters, more versatile and safer inspection capabilities will be needed. Improvements require developments facilitating maneuverability, remote manipulation, and remote sensing. The clear advantages to be gained in conducting underwater operations by eliminating both humans and tethers from the underwater system have thus spurred the development of unmanned, untethered vehicles.

The opportunity to enhance the state-of-the-art development and knowledge of unmanned, untethered underwater vehicles has led the USGS to sponsor the Experimental Autonomous Vehicle Program (EAVE) being jointly investigated by the Naval Ocean Systems Center (NOSC) and the University of New Hampshire (UNH).

The project takes advantage of vehicle programs already in existence at NOSC and UNH. Both vehicles are open framed (Figures 1 and 2), which is ideal for additions, modifications, and comparisons of technologies. The NOSC submersible has been constructed as a test bed to study magnetic navigation and optical fiber communications. The UNH submersible was developed tc study the use of acoustics

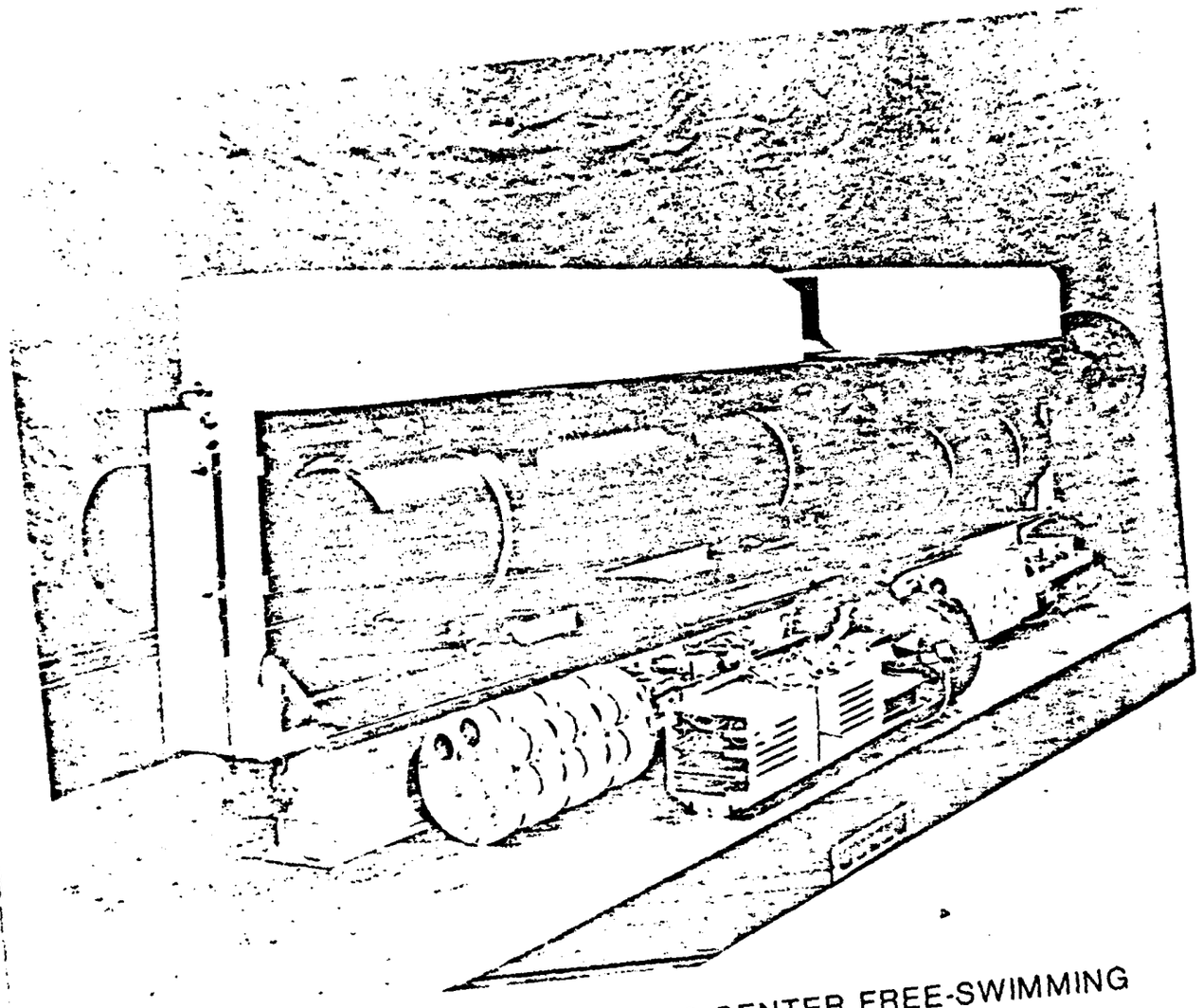


FIGURE 1. NAVAL OCEAN SYSTEMS CENTER FREE-SWIMMING TEST BED VEHICLE

Source: U.S. Department of the Interior, Geological Survey, Research and Development Program for Outer Continental Shelf Oil and Gas Operations, Report for Fiscal Year 1978, compiled by John B. Gregory, Open File Report 78-902.

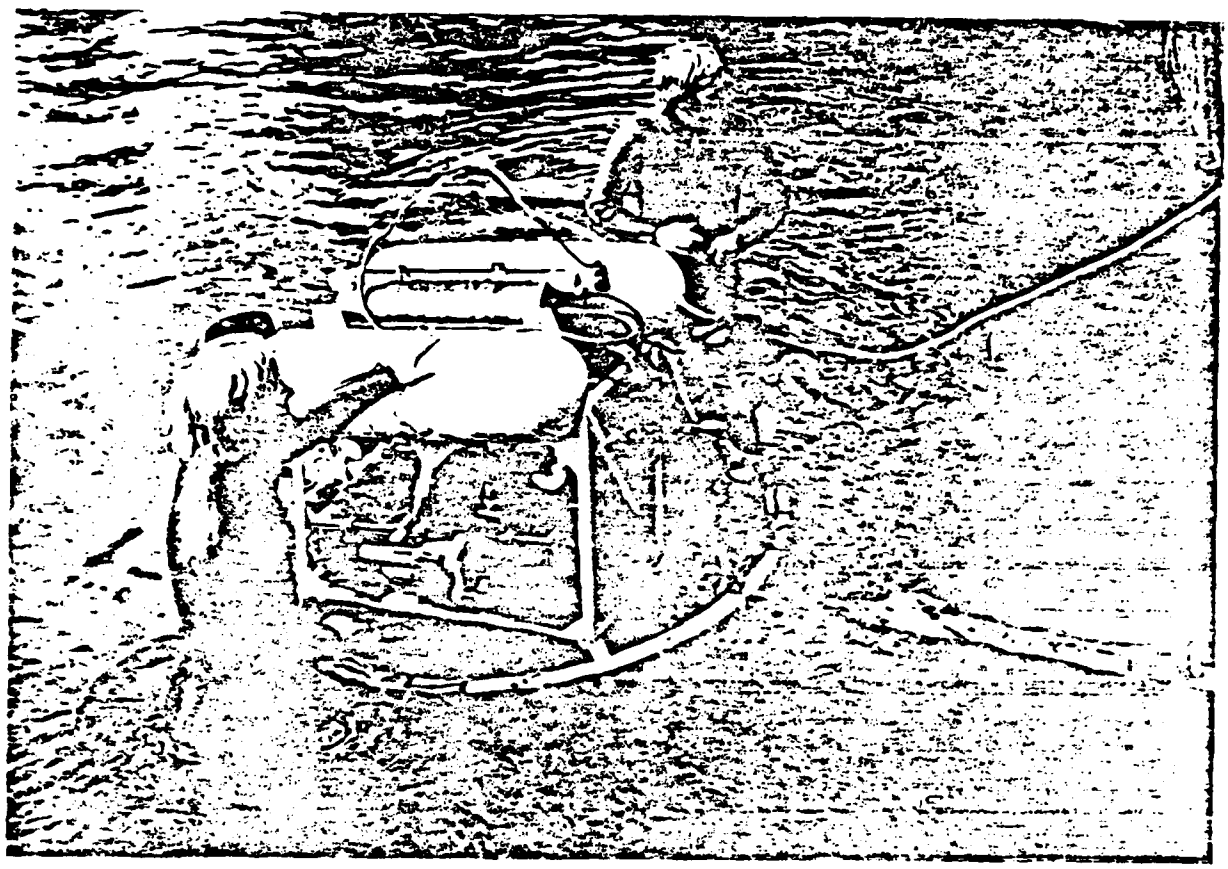


FIGURE 2. UNIVERSITY OF NEW HAMPSHIRE FREE SWIMMING TEST BED VEHICLE

Source: U.S. Department of the Interior, Geological Survey, Research and Development Program for Outer Continental Shelf Oil and Gas Operations, Report for Fiscal Year 1978, compiled by John B. Gregory, Open File Report 78-902.

for both navigation and communications. Both submersibles have been tested in water to perform certain fundamental maneuvers.

The successful development of unmanned, untethered vehicles will enable the safe and efficient inspection of underwater pipelines for their geographical coordinates, oil/gas leakage, and where exposed, for signs of deterioration in their concrete coverings. It will also enable inspections of the submerged portion of offshore oil and gas platforms and other structures during and after installation for defects prejudicial to structural integrity such as cracks and bent, broken, or missing structural members.

The third area where significant research is being conducted by the Survey is in the environmental field. One of the projects the USGS is sponsoring is to determine the toxicity of a variety of drilling fluids (also called drilling mud) on common reef-building corals.

The question of the effects of drilling near coral reefs arose in the early 1970's when an oil company leased offshore tracts near the Texas Flower Gardens bank, a thriving coral reef 110 miles off Galveston, Texas. Although there was no knowledge of possible deleterious effects of drill mud on corals at that time, the Federal Government was sufficiently concerned to place minimum requirements on rig locations and mud and drill cuttings discharges to decrease the possible damages to the coral.

In anticipation of continuing concerns as drilling progresses into other areas of coral growth (Georgia Embayment, Florida Shelf, and Southwest Florida), the R&D program is sponsoring studies at the USGS Fisher Island Station off Miami Beach, Florida, where living corals and clean salt water are readily accessible. The results of the research on the possible harmful effects of drilling substances on marine organisms will have significant impact on the current operating procedures of the oil rigs.

Initial data have been recorded on the possible toxic effects of drilling mud on coral via simulated studies in the laboratory using actual spent drilling muds from Gulf Coast wells. Muds were collected from wells of varying depths (5,000 to 14,000 ft). Specimens of seven species of coral were then placed in aquaria containing muds in suspension at concentrations ranging up to 1,000 ppm whole mud. Through observation and time-lapse photography (Figure 3), the activity of the slow-moving coral polyps and their behavior in response to the muds are observed and compared with control specimens.

The next phase of experimentation is to relate laboratory experimentation to actual situations. Corals will be exposed to various muds in their natural environment in an attempt to relate effects of muds to actual conditions that may exist near a drilling platform.

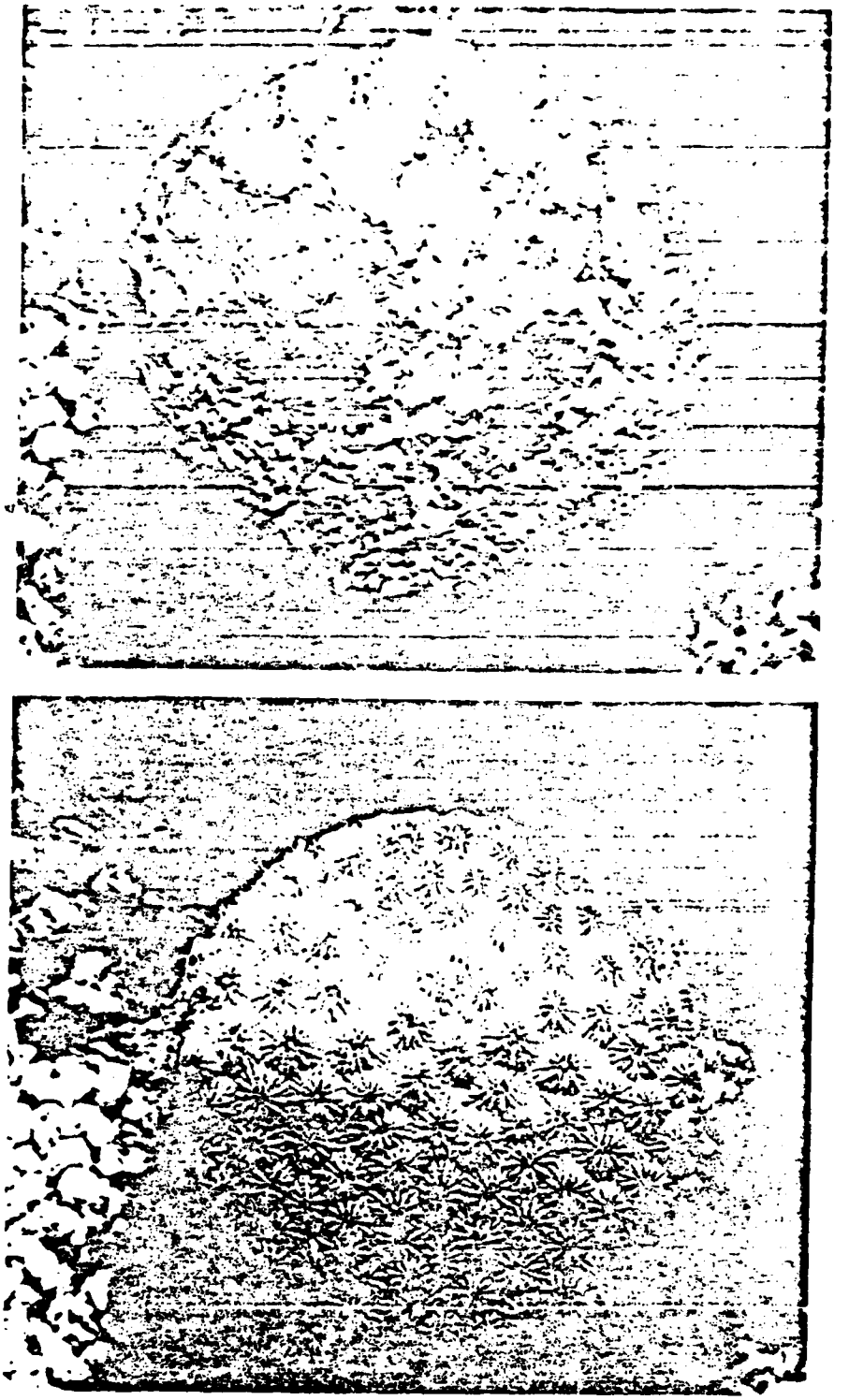


FIGURE 3. VERTICAL VIEW OF CORE OF LIVE CORAL USED IN CLEARING-RATE EXPERIMENT. NOTE MUD PARTIALLY CLEARED FROM CORAL, AT TOP, AND SAME SPECIMEN AFTER CLEARING, AT BOTTOM

Source: U.S. Department of the Interior, Geological Survey, Research and Development Program for Outer Continental Shelf Oil and Gas Operations, Report for Fiscal Year 1978, compiled by John B. Gregory, Open File Report 78-902.

Results of these experiments can provide the regulatory agencies with detailed guidelines for the disposal of drilling muds, drill cuttings, and other materials in the OCS areas.

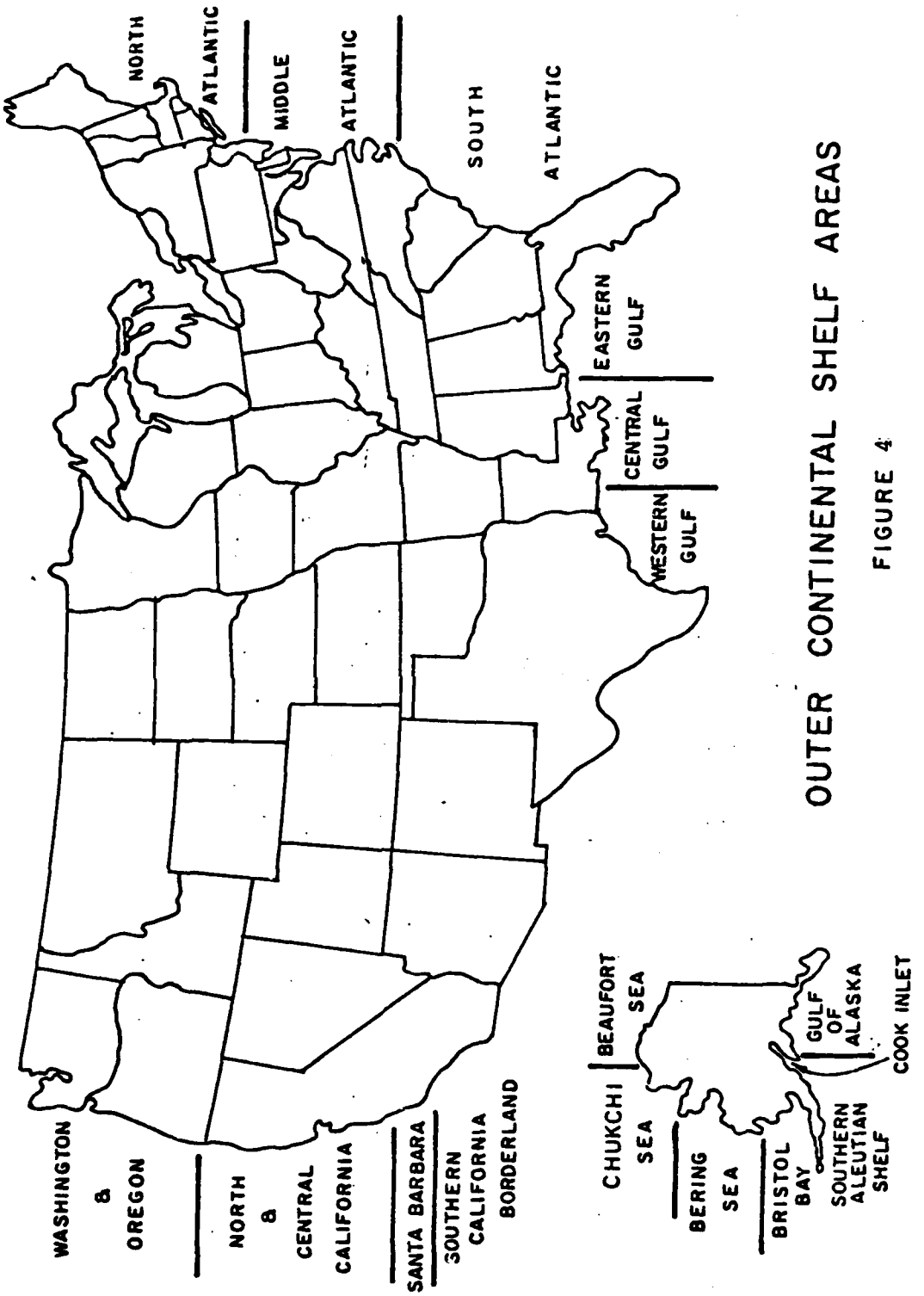
What About the Future?

It has been estimated that 55 to 70 percent of the probable U.S. total oil and gas reserves are located in the continental margin.

Nearly half of these reserves are within reach using current and near-term capabilities; but the remainder, primarily in the Arctic, will call for advances in ocean technology. The most promising offshore areas are shown in Figures 4 and 5. At present, four areas have been explored (offshore Louisiana, Texas, California, and the Cook Inlet of Alaska).

As OCS search and recovery operations expand in frontier areas, new technology and innovative concepts will be required. Each frontier area will present its own unique environmental conditions and problems, imposing special design, construction, and maintenance requirements.

The Geological Survey is meeting the challenge of operational safety and pollution prevention in the offshore environment. It serves as the focal point for identifying specific R&D needs, their priorities, and cost-effectiveness and for bringing concerted effort to meet these needs.



OUTER CONTINENTAL SHELF AREAS

FIGURE 4

Source: National Research Council, Committee on Seafloor Engineering of the Marine Board, Assembly of Engineering, Background Papers on Seafloor Engineering, Vol. I: National Needs in Seafloor Engineering, prepared for the National Science Foundation, 1975.

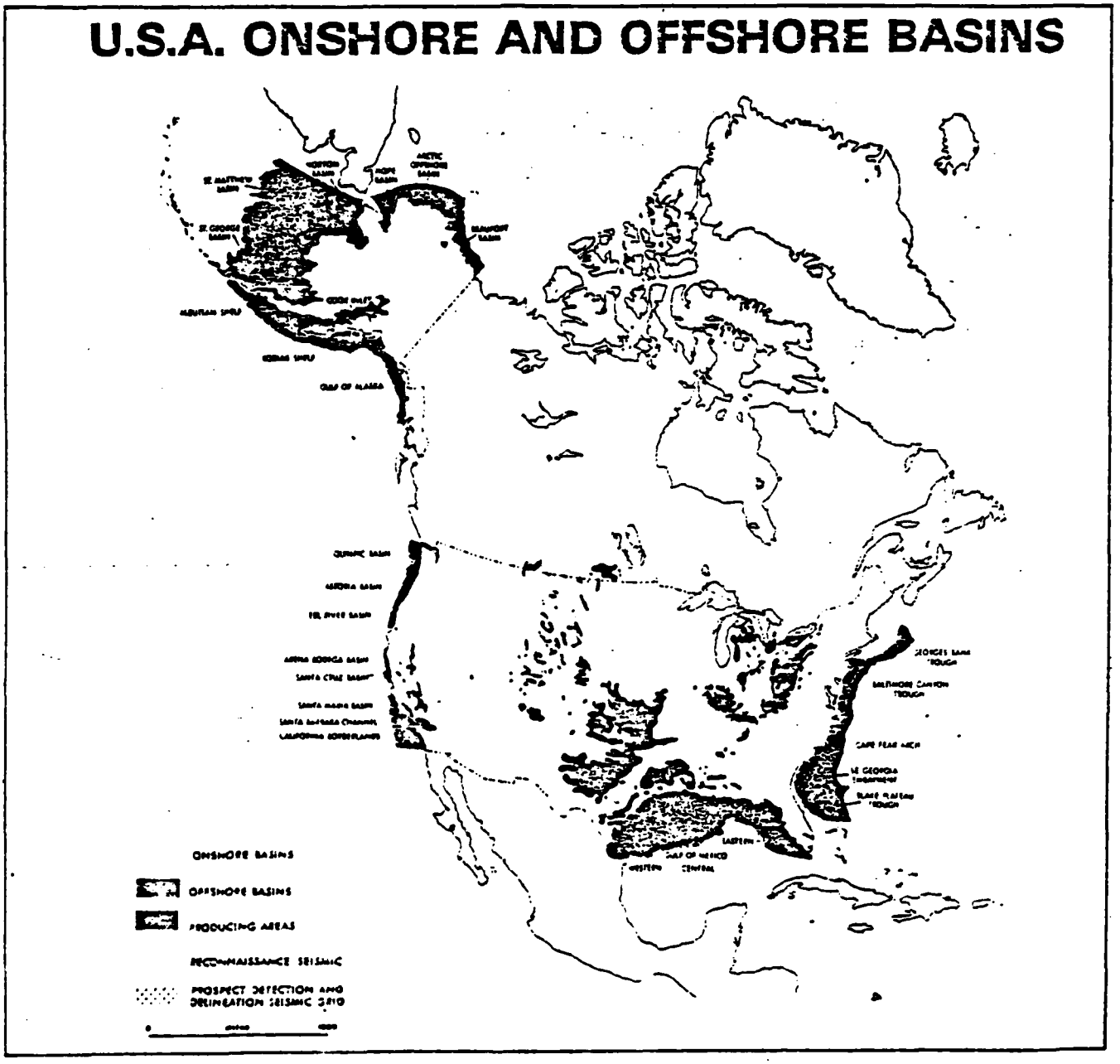
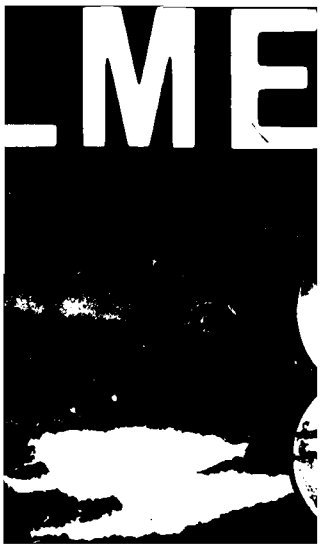


Fig. 5
USA Onshore and Offshore Basins

Source: Maurer Engineering Incorporated, Offshore and Outer Continental Shelf Research and Development Program Definition, prepared for the Energy Research and Development Administration, by Dr. William J. McDonald.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